



U.S. Department  
of Transportation  
**Research and  
Special Programs  
Administration**

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## **INTERNATIONAL SYSTEM OF UNITS (SI) FOR RADIOACTIVE MATERIALS IN TRANSPORTATION**

The information contained in this flyer is intended to aid persons in understanding the relationships between the International System of Units (SI) and the customary units for radiological measurements. It is designed to help in converting values shown in one system to values in the other system.

The sole use of SI units is currently required by most international technical and regulatory organizations. It is the policy of the United States that domestic regulations should be consistent with these international requirements to the greatest degree possible. To provide for adequate safety and radiation protection, it is vital that carriers, package handlers, and all parties potentially having contact with packages containing radioactive materials have a complete understanding of the units used to describe the contents. Therefore, international and domestic organizations have authorized a transition period where information is shown in both the SI and customary units. It must also be noted that the 1996 edition of the International Atomic Energy Agency's Regulations for the Safe Transport of Radioactive Materials, ST-1, requires the sole use of SI units. These regulations go into effect worldwide on January 1, 2001. As a result, all packages of radioactive material are now being prepared for transportation using SI radiological units. The use of SI units primarily affects shipping papers and labels and should have no effect on the manner in which packages containing radioactive materials will be handled under normal and accident transportation conditions. The labels on packages and descriptive information on shipping documents show the measure the radioactive content or the activity. The SI unit used to measure activity is the Becquerel (Bq) and the customary unit is the Curie (Ci). Similarly, international regulations specify radiation levels in SI units. The maximum radiation level at one meter from a package determines the transport index TI, which is shown on labels and shipping papers. The unit of measurement for radiation levels traditionally has been the rem (or a fraction of the rem) per hour. The new SI unit is the Sievert (Sv) per hour.

Since very large numbers are involved with radioactive materials, it is necessary to use numerical abbreviations to write the measured values in a practical way. The following pages provide definitions and abbreviations for numerical factors and for the customary and SI units. Additionally, examples of conversions from customary units to SI radiological and SI to customary units are detailed.

## DEFINITIONS AND ABBREVIATIONS

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### NUMERICAL

Multiplication Factors			Prefix	Symbol
1 000 000 000 000 000 000	=	10 <sup>18</sup>	exa	E
1 000 000 000 000 000	=	10 <sup>15</sup>	peta	P
1 000 000 000 000	=	10 <sup>12</sup>	tera	T
1 000 000 000	=	10 <sup>9</sup>	giga	G
1 000 000	=	10 <sup>6</sup>	mega	M
1 000	=	10 <sup>3</sup>	kilo	k
100	=	10 <sup>2</sup>	hecto	h
10	=	10 <sup>1</sup>	deka	da
0.1	=	10 <sup>-1</sup>	deci	d
0.01	=	10 <sup>-2</sup>	centi	c
0.001	=	10 <sup>-3</sup>	milli	m
0.000 001	=	10 <sup>-6</sup>	micro	u(μ)
0.000 000 001	=	10 <sup>-9</sup>	nano	n
0.000 000 000 001	=	10 <sup>-12</sup>	pico	p
0.000 000 000 000 001	=	10 <sup>-15</sup>	femto	f
0.000 000 000 000 000 001	=	10 <sup>-18</sup>	atto	a

### RADIOLOGICAL

The Curie and Becquerel are units of measure of the quantity or activity of radioactive material which indicates the rate that atoms in the material are undergoing nuclear transformations (disintegrating). The Curie (Ci) is equal to 37 billion disintegrations per second while the Becquerel (Bq) is equal to only one disintegration per second.

The Sievert (Sv) and the rem are health effects related measurements of absorbed radiation.

#### References:

National Council on Radiation Protection and Measurements (NCRP) Report No. 82, "SI Units in Radiation Protection and Measurements", 7910 Woodmont Ave., Bethesda, MD 20814, August 13, 1985.

SI METRIC RADIATION UNITS, Report of the CIRRPC Policy Subpanel, Office of Science and Technology Policy, Executive Office of the President, Washington, DC, December, 1986. (Available from National Technical Information Service (NTIS), Dept. of Commerce, Port Royal Road, Springfield, VA, Accession No. PB87 199386.)

## EQUIVALENTS FOR CONVERSIONS

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### Quantity (activity)

$$1 \text{ TBq} = 27 \text{ Ci} = 27,000 \text{ mCi}$$

$$1 \text{ GBq} = 0.027 \text{ Ci} = 27 \text{ mCi} = 27,000 \text{ uCi}$$

$$1 \text{ MBq} = 0.000027 \text{ Ci} = 0.027 \text{ mCi} = 27 \text{ uCi}$$

$$1 \text{ Ci} = 0.037 \text{ TBq} = 37 \text{ GBq} = 37,000 \text{ MBq}$$

$$1 \text{ mCi} = 0.000037 \text{ TBq} = 37 \text{ MBq}$$

$$1 \text{ uCi} = 0.037 \text{ MBq} = 37,000 \text{ Bq}$$

$$1 \text{ nCi} = 0.000037 \text{ MBq} = 37 \text{ Bq}$$

$$1 \text{ pCi} = 0.037 \text{ Bq} = 37 \text{ mBq}$$

### Radiation Level (dose equivalent rate)

$$1 \text{ Sv/h} = 100 \text{ rem/h} = 100,000 \text{ mrem/h}$$

$$1 \text{ mSv/h} = 0.1 \text{ rem/h} = 100 \text{ mrem/h}$$

$$1 \text{ uSv/h} = 0.0001 \text{ rem/hr} = 0.1 \text{ mrem/h}$$

$$1 \text{ rem/h} = 0.01 \text{ Sv/h} = 10 \text{ mSv/h} = 10,000 \text{ uSv/h}$$

$$1 \text{ mrem/h} = 0.00001 \text{ Sv/h} = 0.01 \text{ mSv/h} = 10 \text{ uSv/h}$$

## USE OF CONVERSION FACTORS

To convert a value from one system of units to the other:

First, in the left column find the unit you wish to convert from.

Second, find the factor in that line for the unit you wish to convert to.

Third, multiply the original value by the factor and the result will be the measure in the desired units.

**Examples:**

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1. A radioactive material label shows 14 TBq. How many Curies is it?

$$14 \text{ TBq} \times 27 \text{ Ci per TBq} = 378 \text{ Ci}$$

2. We have 50 MBq of a radioactive material in a package. How many millicuries is it?

$$50 \text{ MBq} \times 0.027 \text{ mCi per MBq} = 1.35 \text{ mCi}$$

3. The regulations state that for a material to be considered radioactive for transport, the specific activity must be greater than 0.002 uCi per gram. What is this lower limit in Becquerels?

$$0.002 \text{ uCi/gram} \times 37,000 \text{ Bq per uCi} = 74 \text{ Bq/gram}$$

4. How many TBq are equal to 500 Curies?

$$500 \text{ Curies} \times 0.037 \text{ TBq per Ci} = 18.5 \text{ TBq}$$

5. The EPA standards require that public drinking water systems limit the natural radium concentration to less than 5 pCi per liter. What is this upper limit in Becquerels?

$$5 \text{ pCi per liter} \times 0.037 \text{ Bq per pCi} = 0.185 \text{ Bq/liter}$$

6. Earlier international and current domestic regulations define the Transport Index (TI) of a package as the number equal to the maximum radiation level in millirem per hour at a distance of one meter from the package. A TI of 1.0 corresponds to a radiation level of 1 mrem/h at one meter. What is the radiation level in microsieverts per hour which corresponds to a TI of 2.5?

$$2.5 \text{ TI} \times 1.0 \text{ mrem/h per TI} \times 10 \text{ uSv per mrem} = 25 \text{ uSv/h}$$

7. The maximum surface radiation level for a package with a Radioactive Yellow II label is 50 millirem per hour. Would a measured radiation level of 380 uSv/h be acceptable for a Radioactive Yellow II label?

$$380 \text{ uSv/h} \times 0.1 \text{ mrem/h per uSv/h} = 38 \text{ mrem/h}$$

Yes, since 38 mrem/h is less than 50 mrem/h.

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